OPEN-FILE REPORT 98-24

SEISMIC HAZARD EVALUATION OF THE SAN PEDRO 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

1998

DEPARTMENT OF CONSERVATION
Division of Mines and Geology

STATE OF CALIFORNIA
GRAY DAVIS
GOVERNOR

THE RESOURCES AGENCY
MARY D. NICHOLS
SECRETARY FOR RESOURCES

DEPARTMENT OF CONSERVATION
DARRYL YOUNG
DIRECTOR

DIVISION OF MINES AND GEOLOGY
JAMES F. DAVIS, *STATE GEOLOGIST*

OPEN-FILE REPORT 98-24

SEISMIC HAZARD EVALUATION OF THE SAN PEDRO 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

DIVISION OF MINES AND GEOLOGY'S PUBLICATION SALES OFFICES:

Southern California Regional Office
655 S. Hope Street, Suite 700
Los Angeles, CA 90017
(213) 239-0878

Publications and Information Office
801 K Street, MS 14-31
Sacramento, CA 95814-3531
(916) 445-5716

Bay Area Regional Office
185 Berry Street, Suite 210
San Francisco, CA 94107-1728
(415) 904-7707

CONTENTS

ILLUSTRATIONS

PREFACE

With the increasing public concern about the potential for destructive earthquakes in northern and southern California, the State Legislature passed the Seismic Hazards Mapping Act in 1990. The purpose of the Act is to protect the public from the effects of strong ground shaking, liquefaction, landslides or other ground failure, and other hazards caused by earthquakes. The program and actions mandated by the Seismic Hazards Mapping Act closely resemble those of the Alquist-Priolo Earthquake Fault Zoning Act (which addresses only surface fault-rupture hazards) and are outlined below:

1. **The State Geologist** is required to delineate the various "seismic hazard zones."

2. **Cities and Counties**, or other local permitting authorities, must regulate certain development "projects" within the zones. They must withhold the development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans.

3. **The State Mining and Geology Board (SMGB)** provides additional regulations, policies, and criteria to guide cities and counties in their implementation of the law. The SMGB also provides criteria for preparation of the Seismic Hazard Zone Maps (Web site http://www.consrv.ca.gov/dmg/shezp/zoneguid/) and for evaluating and mitigating seismic hazards.

4. **Sellers (and their agents)** of real property within a mapped hazard zone must disclose at the time of sale that the property lies within such a zone.

As stated above, the Act directs the State Geologist, through the Division of Mines and Geology (DMG) to delineate seismic hazard zones. Delineation of seismic hazard zones is conducted under criteria established by the Seismic Hazards Mapping Act Advisory Committee and its Working Groups and adopted by the California SMGB.

The Official Seismic Hazard Zone Maps, released by DMG, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available from:

BPS Reprographic Services
149 Second Street
San Francisco, California 94105
(415) 512-6550

Seismic Hazard Evaluation Reports, released as Open-File Reports (OFR), summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These Open-File Reports are available for reference at DMG offices in Sacramento,

San Francisco, and Los Angeles. Copies of the reports may be purchased at the Sacramento, Los Angeles, and San Francisco offices. In addition, the Sacramento office offers prepaid mail order sales for all DMG OFRs. **NOTE: The Open-File Reports are not available through BPS Reprographic Services.**

DIVISION OF MINES AND GEOLOGY OFFICES

Geologic Information and Publications Office
801 K Street, MS 14-33
Sacramento, CA 95814-3532
(916) 445-5716

Bay Area Regional Office
185 Berry Street, Suite 210
San Francisco, CA 94107-1728
(415) 904-7707

Southern California Regional Office
655 S. Hope Street, Suite 700
Los Angeles, CA 90017
(213) 239-0878

WORLD WIDE WEB ADDRESS

Seismic Hazard Evaluation Reports and additional information on seismic hazard zone mapping in California are available on the Division of Mines and Geology's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

The Act also directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. They also directed DMG to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that the 1) process for zoning liquefaction hazards remain unchanged and that 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Evaluation Report summarizes the development of the hazard zone map for each area. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historic high-water-table information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the San Pedro 7.5-minute Quadrangle (scale 1:24,000).

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the San Pedro 7.5-Minute Quadrangle, Los Angeles County, California

By
Richard B. Greenwood

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the San Pedro 7.5-minute Quadrangle (scale 1:24,000). This section and Section 2 addressing earthquake-induced landslides, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazards zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Liquefaction-induced ground failure has historically been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated granular sediments within the upper 40 feet of the ground surface. These geological and ground-water conditions exist in parts of southern California, most notably in some densely populated valley regions and alluviated floodplains. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region in general, as well as in the San Pedro Quadrangle.

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils is generally confined to areas covered by Quaternary sedimentary deposits. Such areas consist mainly of alluviated valleys, floodplains, and canyon regions. The evaluation is based on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth data, most of which are gathered from a variety of sources. The quality of the data used varies. Although selection of data used in this evaluation was rigorous, the state of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth and thickness of liquefiable sediments, depth to ground water, rate of drainage, slope gradient, proximity to free-face conditions, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to determine the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction potential, opportunity, susceptibility, and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The onshore portion of the San Pedro Quadrangle covers an area of about 10 square miles in southwestern Los Angeles County. The map area includes portions of the cities of Rancho Palos Verdes, which contains the communities of Portuguese Bend and Miraleste, Rolling Hills, the Los Angeles City communities of San Pedro and East San Pedro, and part of Los Angeles Harbor.

Topographically, the San Pedro Quadrangle covers part of the southern slopes of the Palos Verdes Hills. Steep cliffs and several coves and headlands, including Whites Point and Point Fermin, characterize the rugged southeast-trending coastline of the hills. In the northeastern corner of the quadrangle San Pedro sits upon both the eastern slopes of the Palos Verdes Hills and an area of highly modified beach deposits and artificial fill. The sprawling Los Angeles Harbor facilities, including Terminal Island, extend into San Pedro Bay. Elevations range from sea level to about 1460 feet near the crest of San Pedro Hill.

The San Pedro Quadrangle is in the southwestern block of the Los Angeles Basin. Along the coast are Pleistocene wave-cut marine platforms, which are covered by marine deposits. Subsequent erosion of the bordering hilly areas generated nonmarine colluvial cover that veneers some of the terraces. Major landslide complexes occur in the northwestern corner of the quadrangle. Alluvium and slope wash deposits occur within the major drainages in some areas.

Access to the quadrangle is provided by the Harbor Freeway (I-110), Palos Verdes Drive South, Palos Verdes Drive East, Western Avenue, and Crest Road. The Vincent Thomas Bridge connects the Palos Verdes Peninsula, at San Pedro, with Terminal Island.

GEOLOGIC CONDITIONS

Surface Geology

A digital map obtained from the U.S.Geological Survey (Tinsley, unpublished) was used as a base to prepare a geologic map of the San Pedro Quadrangle for this project. Additional detail was added from a digital map prepared by the Southern California Areal Mapping Project (SCAMP, unpublished) and the California Division of Mines and Geology (Bezore and others, unpublished), which was compiled primarily from mapping by Woodring and others (1946). Quaternary geologic contacts received minor modifications in accordance with an older 1:20,000-scale U.S. Geological Survey topographic map (Wilmington, 1925), the 1:62,500-scale San Pedro (1896) and Redondo quadrangles (1944), and an older regional soils map (Nelson and others, 1919). Stratigraphic nomenclature was revised to follow the format developed by SCAMP (Morton and Kennedy, 1989). The revised geologic map that was used in this study of liquefaction susceptibility is included as Plate 1.1.

Woodring and others (1946) recognized the early Pleistocene Lomita Marl (Ql), as the oldest Quaternary geologic unit in the San Pedro Quadrangle. The Lomita Marl is overlain by the early Pleistocene sandy silt and silty sand of the Timms Point Silt (Qtp), and the early Pleistocene San Pedro Formation (Qsp), a massive, poorly consolidated, light brown marine sand deposit exposed in the Palos Verdes Hills. Woodring and others (1946) also mapped multiple levels of Pleistocene marine terraces with dense silty sand terrace deposits (Qter) in the Palos Verdes Hills. Local drainages are incised and filled with soft, locally derived sandy silt and sandy clay of the younger alluvium (Qya2) unit. Modern beach deposits (Qm), which consist of well-sorted, medium- to coarse-grained sand, form the discontinuous beaches on the Palos Verdes Peninsula. A more detailed description of the bedrock geology of the Palos Verdes Hills is presented in Section II.

Prior to the development of Los Angeles Harbor, extensive estuarine deposits were present at the mouth of Bixby Slough and the Los Angeles River. These organic tidal muds were extensively dredged and have been extensively covered with artificial fill (af).

Subsurface Geology and Geotechnical Characteristics

As liquefaction analysis for the San Pedro Quadrangle focused on areas of artificial fill, beach sands, and localized alluvial fill of minor drainages. Data from twelve boreholes were collected for this study at the Regional Water Quality Control Board. Also reviewed were DMG files of seismic reports for hospitals, school site files from the State Architect's Office, and local water well logs from the California Department of Water Resources. Geotechnical data, particularly SPT blow counts, from environmental studies are sometimes less reliable however, due to the use of non-standard equipment and incomplete reporting of procedures.

Data from borehole logs were entered into the DMG Geographic Information System (GIS) database. Locations of all exploratory boreholes entered into the database for consideration in this investigation are shown on Plate 1.2.

Descriptions of characteristics of geologic units are given below. These descriptions are necessarily generalized, but give the most commonly encountered characteristics of the units (see Table 1.1).

Lomita Marl (Ql), Timms Point Silt (Qtp), and San Pedro Sand (Qsp)

The Lomita Marl, Timms Point Silt and San Pedro Sand were mapped by Woodring and others (1946) on the Palos Verdes Peninsula. Lomita Marl is typically composed of dense, ridge-forming silty sand, sand, and clayey sand. The lower Pleistocene Timms Point Silt is typically composed of dense sandy silt and silty sand. The lower Pleistocene San Pedro Sand is typically composed of cross-bedded to massive sand and silty sand.

Marine terrace deposits (Qter)

Late Pleistocene marine terrace deposits that generally consist of silty sand with local gravels are found throughout the Palos Verdes Peninsula.

Geologic Map Unit	Material Type	Consistency	Liquefaction Susceptibility
af, artificial fill	sand, silty sand	soft to dense	high
Qm, beach sand	Sand	Soft	high
Qya2, younger alluvium	silty sand, and sand	soft to moderately dense	high
Qter, older marine terrace	silty sand, minor gravel	dense-very dense	low
Qsp, San Pedro sand	sand, silty sand, minor gravel	loose to moderately dense	low
Qtp, Timms Point silt	Sandy silt, silty sand	dense	low
Ql, Lomita Marl	fossiliferous coarse sand	dense-very dense	low

Table 1.1. General geotechnical characteristics and liquefaction susceptibility of younger Quaternary units.

Younger alluvium (Qya2)

Younger alluvium associated with the lowlands of Bixby Slough-Harbor Lake (in the adjacent Torrance Quadrangle) and local drainages of the San Pedro area were not subdivided into "alluvium" and "floodplain" deposits by (Tinsley, unpublished). These deposits consist of soft silts and clays with some loose to moderately dense silty sand.

Modern beach deposits (Qm)

Modern beach deposits (Qm), which consist of well sorted, medium- to coarse-grained sand, form the discontinuous beaches on the Palos Verdes Peninsula.

Artificial fill (af)

Artificial fill in the San Pedro Quadrangle consists of undifferentiated artificial fills of various ages associated with development of the greater Los Angeles Harbor complex.

GROUND-WATER CONDITIONS

A ground-water evaluation of alluviated areas was performed in order to determine historically shallowest ground-water levels in the San Pedro Quadrangle. Areas characterized by historical groundwater or perched water with depths of less than 40 feet are considered for the purposes of liquefaction hazard zoning. The evaluation was based on first-encountered water levels encountered in geotechnical boreholes and selected water wells. Turn-of-the-century water-well logs and data (Mendenhall, 1905) were also reviewed but were generally found to be inadequate for the purposes of this study. As noted by Poland and others (1959, p. 90): recent topographic maps differ considerably from the land surface modeled by the 25-foot contour interval of the 1894 base map. Mendenhall (1905) contoured all available water levels--from all aquifers. For the current evaluation the depths to first-encountered water free of piezometric influences were plotted and contoured on a map showing depths to historically shallowest ground water (Plate 1.2). This map was digitized and used for the liquefaction analysis.

PART II

EVALUATING LIQUEFACTION POTENTIAL

Liquefaction occurs in water-saturated sediments during moderate to great earthquakes. Liquefied sediments are characterized by a loss of strength and may fail, causing damage to buildings, bridges, and other such structures. A number of methods for mapping liquefaction hazard have been proposed; Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of susceptibility units, and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce liquefaction potential. Liquefaction susceptibility is a function of the capacity of sediments to resist liquefaction and liquefaction opportunity is a function of the seismic ground shaking intensity. The application of the Seed Simplified Procedure (Seed and Idriss, 1971) for evaluating liquefaction potential allows a quantitative characterization of susceptibility of geologic units. Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for mapping liquefaction hazards in the Los Angeles region. The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985), combining geotechnical data analyses, and geologic and hydrologic mapping, but follows criteria adopted by the California State Mining and Geology Board (in press).

LIQUEFACTION OPPORTUNITY

According to the criteria adopted by the California State Mining and Geology Board (in press), liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for ground shaking strong enough to generate liquefaction. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10% probability of exceedance over a 50-year period. The earthquake magnitude is the magnitude that contributes most to the acceleration.

For the San Pedro Quadrangle, a peak acceleration of 0.54 g resulting from an earthquake of magnitude 7.0 to 7.1 was used for liquefaction analyses. The PGA and magnitude values were derived from maps prepared by Petersen and others (1996) and Cramer and Petersen (1996), respectively. See the ground motion section of this report for further details.

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of soils to loss of strength when subjected to ground shaking. Primarily, physical properties and conditions of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance. These properties and conditions are correlated with geologic age and environment of deposition. With increasing age of a deposit, relative density may increase through cementation of the particles or the increase in thickness of the overburden sediments. Grain size characteristics of a soil also influence susceptibility to liquefaction. Sands are more susceptible than silts or gravels, although silts of low plasticity are treated as liquefiable in this investigation. Cohesive soils are generally not considered susceptible to liquefaction. Such soils may be vulnerable to strength loss with remolding and represent a hazard that is not addressed in this investigation. Soil characteristics and processes that result in lower liquefaction susceptibility generally result in higher penetration resistances to the soil sampler. Different blow count corrections are used for silty sand and nonplastic silt than for clean sand (Seed and others, 1985). Therefore, blow count or cone penetrometer values are a useful indicator of liquefaction susceptibility.

Saturation is required for liquefaction, and the liquefaction susceptibility of a soil varies with the depth to ground water. Very shallow ground water increases the susceptibility to liquefaction (more likely to liquefy). Soils that lack resistance (susceptible soils) are typically saturated, loose sandy sediments. Soils resistant to liquefaction include all soil types that are dry or sufficiently dense.

DMG’s map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil-property and soil-condition factors such as type, age, texture, color, and consistency, along with historic depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, findings can be related to the map units. DMG’s qualitative susceptible soil inventory is summarized on Table 1.1.

Lomita Marl (Ql), Timms Point Silt (qtp), and San Pedro Sand (Qsp)

The Lomita Marl typically is composed of dense, ridge-forming silty sand, sand, and clayey sand. The lower Pleistocene Timms Point Silt is composed of dense sandy silt and silty sand. The lower Pleistocene San Pedro Sand is typically composed of cross-bedded to massive sand and silty sand. All of these units predate the late Pleistocene age restrictions of this program, and are assigned a low liquefaction susceptibility.

Marine terrace deposits (Qter)

Marine terrace deposits are composed of dense to very dense sands and silty sands. Liquefaction susceptibility of these units is low.

Younger alluvium (Qya2)

Younger alluvium consists of soft silts and clays with some loose to moderately dense silty sand. Where this unit is saturated, or located within incised and filled drainages that may be subject to seasonal saturation, liquefaction susceptibility is high.

Beach sands (Qma)

Modern beach deposits (Qm), which consist of well-sorted, medium- to coarse-grained sand, form the discontinuous beaches on the Palos Verdes Peninsula.

Artificial fill (af)

Artificial fills commonly overlie young alluvial or estuarine deposits. Because the artificial fills are usually too thin to affect the liquefaction hazard, and the underlying estuarine and alluvial deposits have a high liquefaction susceptibility, they are assumed to have a high susceptibility to liquefaction.

Quantitative Liquefaction Analysis

DMG performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; Seed and Harder, 1990; Youd and Idriss, 1997). This procedure calculates soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR) based on standard penetration test (SPT) results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). The factor of safety (FS) relative to liquefaction is: FS=CRR/CSR. FS, therefore, is a quantitative measure of liquefaction potential. Generally, a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, indicates the presence of potentially liquefiable soil. DMG uses FS, as well as other considerations such as slope, free face conditions, and thickness and depth of potentially liquefiable soil, to construct liquefaction potential maps, which then directly translate to Zones of Required Investigation.

Five borehole logs compiled for this study had blow counts from standard penetration tests or from tests that could be converted to SPTs. Few included all of the required information (SPTs, density, water content, percentage of silt and clay size grains) for a complete Seed Simplified analysis. For those boreholes where SPTs were recorded, the liquefaction analysis was conducted either using data from that borehole or if the other data were lacking, extrapolated from nearby boreholes in similar materials.

LIQUEFACTION ZONES

Criteria for Zoning

The areas underlain by late Quaternary geologic units were included in liquefaction zones using the criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the California State Mining and Geology Board (in press). Under those criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historic earthquakes.
2. All areas of uncompacted fills containing liquefaction susceptible material that are saturated, nearly saturated, or may be expected to become saturated.
3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable.
4. Areas where existing geotechnical data are insufficient**.**

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historic high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (between 11,000 years and 15,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historic high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria for liquefaction zoning in the San Pedro Quadrangle is summarized below.

Areas of Past Liquefaction

In the San Pedro Quadrangle, numerous effects attributed to liquefaction were noted in San Pedro District following the 1933 Long Beach earthquake. The effects include: numerous leaks in gas lines, broken water mains, a foot-wide crack in the apron of the terminal at berth 156-160, and "mud volcanoes" at Cabrillo Beach (Barrows, 1974; see Plate 1.2).

Part of the Port of Los Angeles is situated in the northeasternmost corner of the San Pedro Quadrangle. During the 1994 Northridge earthquake significant damage occurred to facilities near Berths 121 to 126 and at Pier 300 in the adjacent Torrance Quadrangle (Stewart and others, 1994, p. 135). Features that developed at these localities, such as lateral spreading, settlement, and sand boils, manifested liquefaction.

Artificial Fills

In the San Pedro Quadrangle, artificial fill includes engineered fill around the Los Angeles Harbor area and throughout the Palos Verdes Peninsula. Residential-related engineered fills are generally too thin to have an impact on liquefaction. Fills that overlie estuarine deposits, however, are more likely to be susceptible to liquefaction. Extensive low-lying areas of artificial fill have been included in liquefaction hazard zones.

Areas with Existing Geotechnical Data

The Lomita Marl (Ql), Timms Point Silt (Qtp), San Pedro Sand (Qsp), and marine terrace (Qter) deposits exposed in the San Pedro Quadrangle generally have a dense consistency, high fines content, or deep ground water, or exceed the latest Pleistocene age limit of the liquefaction criteria and, accordingly, have not been included in liquefaction hazard zones.

Younger alluvial deposits (Qya2) and beach sands (Qm) commonly have layers of loose silty sand or sand. Where these deposits are saturated, they are included in a liquefaction hazard zone.

ACKNOWLEDGMENTS

The author would like to thank the staff at the California Department of Transportation (Caltrans), and the Los Angeles Regional Water Quality Control Board for their assistance in the collection of subsurface borehole data. John Tinsley of the U.S. Geological Survey graciously shared information from his extensive files of subsurface geotechnical data for this area. At DMG, special thanks to Bob Moskovitz, Teri McGuire, Barbara Wanish, and Scott Shepherd for their GIS operations support, and to Barbara Wanish for designing and plotting the graphic displays associated with the liquefaction zone map and this report.

REFERENCES

Barrows, A.G., 1974, A review of the geology and earthquake history of the Newport-Inglewood structural zone, Southern California: California Division of Mines and Geology Special Report 114, 115 p., scale 1:125,000.

Bezore, S.P., Saucedo, G.J. and Greenwood, R. G., (unpublished), Geologic Map of the Long Beach 100,000-scale Quadrangle.

California State Mining and Geology Board, 1997, Guidelines for evaluating and mitigating seismic hazards in California: California Department of Conservation, Division of Mines and Geology, Special Publication 117, 74 p.

California State Mining and Geology Board, in press, Criteria for delineating seismic hazard zones: California Department of Conservation, Division of Mines and Geology, Special Publication 118, 21 p.

Cramer, C.H. and Petersen, M.D., 1996, Predominant seismic source distance and magnitude maps for Los Angeles, Orange, and Ventura counties, California: Bulletin of Seismological Society of America, v. 86, no. 5, p. 1,645-1,649.

Mendenhall, W.C., 1905, Development of underground waters in the western coastal plain region of southern California: U.S. Geological Survey Water-Supply Paper 139, 105 p.

Morton, D.M. and Kennedy, M.P., 1989, A southern California digital 1:100,000-scale geologic map series: The Santa Ana Quadrangle, The first release: Geological Society of America Abstracts with Programs v. 21, no. 6, p. A107-A108.

Nelson, J.W., Zinn, C.J., Strahorn, A.T., Watson, E. B. and Dunn, J.E., 1919, Soil survey of the Los Angeles area, California: U.S. Department of Agriculture, Bureau of Soils, 78 p., map scale 1:62,500.

Petersen, M.D., Cramer, C.H., Bryant, W.A., Reichle, M.S. and Toppozada, T.R., 1996, Preliminary seismic hazard assessment for Los Angeles, Ventura, and Orange counties, affected by the 17 January 1994 Northridge earthquake: Bulletin of the Seismological Society of America, v. 86, no. 1B, p. S247-S261.

Poland, J.E., Garrett, A.A. and Sinotte, A., 1959, Geology, hydrology, and chemical character of ground waters in the Torrance-Santa Monica area, California: U.S. Geological Survey Water Supply Paper 1461, 425 p., Plate 1, north half, map scale 1: 31,680.

Poland, J.E., Piper, A.M. and others, 1956, Ground-water geology of the coastal zone Long Beach-Santa Ana area, California: U.S. Geological Survey Water Supply Paper 1109, 162 p., Plate 2, southern half, map scale 1:31,680.

Seed, H.B. and Idriss, I.M., 1971, Simplified procedure for evaluating soil liquefaction potential: Journal of the Soil Mechanics and Foundations Division of ASCE, v. 97: SM9, p. 1,249-1,273.

Seed, H.B., Idriss, I.M. and Arango, Ignacio, 1983, Evaluation of liquefaction potential using field performance data: Journal of Geotechnical Engineering, v. 109, no. 3, p. 458-482.

Seed, H.B., Tokimatsu, Kohji, Harder, L.F. and Chung, R.M., 1985, Influence of SPT procedures in soil liquefaction resistance evaluations: Journal of Geotechnical Engineering, ASCE, v. 111, no. 12, p. 1,425-1,445.

Seed, R.B. and Harder, L.F., 1990, SPT-based analysis of cyclic pore pressure generation and undrained residual strength: Proceedings of the H. Bolton Seed Memorial Symposium, v. 2, p. 351-376.

Smith, T.C., 1996, Preliminary maps of seismic hazard zones and draft guidelines for evaluating and mitigating seismic hazards: California Geology, v. 49, no. 6, p. 147-150.

Southern California Areal Mapping Project, unpublished, Digital geologic map of the San Pedro 7.5-minute Quadrangle, scale 1:24,000.

Stewart, J.P., Bray, J.D., Seed, R.B. and Sitar, Nicholas, *editors*, 1994, Preliminary report on the principal geotechnical aspects of the January 17, 1994 Northridge earthquake: University of California at Berkeley, College of Engineering Report No. UCB/EERC - 94-08, 245 p.

Tinsley, J.C., unpublished, Digital Quaternary geologic map of the San Pedro 7.5-minute Quadrangle, California: U. S. Geological Survey: compilation scale 1:24,000.

Tinsley, J.C. and Fumal, T.E., 1985, Mapping Quaternary sedimentary deposits for areal variations in shaking response, *in* Ziony, J.I., *editor*, Evaluating earthquake hazards in the Los Angeles Region -- An earth-science perspective: U.S. Geological Survey Professional Paper 1360, p. 101 - 125.

Tinsley, J.C., Youd, T.L., Perkins, D.M. and Chen, A.T.F., 1985, Evaluating liquefaction potential, *in* Ziony, J.I. *editor*, Evaluating earthquake hazards in the Los Angeles region --An earth science perspective: U.S. Geological Survey Professional Paper 1360, p 263-315.

USGS (U.S. Geological Survey), 1896 edition, Topographic map of the San Pedro 15-minute Quadrangle, scale 1:62,500, contour interval 25 feet.

USGS (U.S. Geological Survey), 1944 edition, Topographic map of the Redondo 15-minute Quadrangle, scale 1:62,500, contour interval 25 feet.

USGS (U.S. Geological Survey), 1925 edition, Topographic map of the Wilmington 6-minute Quadrangle, scale 1:24,000, contour interval 5 feet.

Youd, T.L., 1991, Mapping of earthquake-induced liquefaction for seismic zonation: Earthquake Engineering Research Institute, Proceedings, Fourth International Conference on Seismic Zonation, v. 1, p. 111-138.

Youd, T.L. and Idriss, I.M., 1997, *editors*, Proceedings of the NCEER workshop on evaluation of liquefaction resistance of soils: National Center for Earthquake Engineering Research Technical Report NCEER-97-0022, 276 p.

Youd, T.L. and Perkins, D.M. 1978, Mapping liquefaction-induced ground failure potential: Journal of Geotechnical Engineering, v. 104, p. 433-446.

SECTION 2

EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the San Pedro 7.5-Minute Quadrangle, Los Angeles County, California

By

Jack R. McMillan and Wayne D. Haydon

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the San Pedro 7.5-minute Quadrangle (scale 1:24,000). This section and Section 1 addressing liquefaction, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Landslides triggered by earthquakes have historically been a major cause of earthquake damage. Landslides triggered by the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes were responsible for destroying or damaging numerous homes and other structures, blocking major transportation corridors, and damaging various types of life-line infrastructure. Typically, areas most susceptible to earthquake-induced landslides are on steep slopes and on or adjacent to existing landslide deposits, especially if the earth materials in these areas are composed of loose colluvial soils, or poorly cemented or highly fractured rocks. These geologic and terrain conditions exist in many parts of southern California, most notably in hilly areas already developed or currently undergoing development. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region, which includes the San Pedro Quadrangle.

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered primarily from a variety of outside sources; thus, the quality of the data is variable. Although the selection of data used in this evaluation was rigorous, the state of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Earthquake-generated ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. No attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the San Pedro Quadrangle, for more information on the delineation of liquefaction zones.

Information developed in the study is presented in two parts: physiographic, and geologic conditions in PART I, and ground shaking opportunity, landslide hazard potential and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The onshore portion of the San Pedro Quadrangle covers an area of about 10 square miles in southwestern Los Angeles County. The map area includes portions of the cities of Rancho Palos Verdes, which contains the communities of Portuguese Bend and Miraleste, Rolling Hills, the Los Angeles City communities of San Pedro and East San Pedro, and part of Los Angeles Harbor.

Topographically, the San Pedro Quadrangle covers part of the southern slopes of the Palos Verdes Hills. Steep cliffs and several coves and headlands, including Whites Point and Point Fermin, characterize the rugged southeast-trending coastline of the hills. In the northeastern corner of the quadrangle San Pedro sits upon both the eastern slopes of the Palos Verdes Hills and an area of highly modified beach deposits and artificial fill. The sprawling Los Angeles Harbor facilities, including Terminal Island, extend into San Pedro Bay. Elevations range from sea level to about 1460 feet near the crest of San Pedro Hill.

The San Pedro Quadrangle is in the southwestern block of the Los Angeles Basin. Along the coast are Pleistocene wave-cut marine platforms, which are covered by marine deposits. Subsequent erosion of the bordering hilly areas generated nonmarine colluvial cover that veneers some of the terraces. Major landslide complexes occur in the northwestern corner of the quadrangle. Alluvium and slope wash deposits occur within the major drainages in some areas.

Access to the quadrangle is provided by the Harbor Freeway (I-110) Palos Verdes Drive South, Palos Verdes Drive East, Western Avenue, and Crest Road. The Vincent Thomas Bridge connects the Palos Verdes Peninsula, at San Pedro, with Terminal Island.

GEOLOGIC CONDITIONS

Surface and Bedrock Geology

For the San Pedro Quadrangle, bedrock geologic mapping at a scale of 1:24,000 has been published by Woodring and others (1946). Cleveland (1976) also published geologic maps covering portions of the Palos Verdes Hills at 1:12,000 scale. These sources were compiled, digitized and presented at 1:100,000 scale in Bezore and others (unpublished). This digitized compilation formed the basis of the geologic map used in this investigation. The digital geologic map was modified to reflect the most recent mapping in the area and to include interpretations of observations made during the aerial photograph landslide inventory and field reconnaissance. In the field, observations were made of exposures, aspects of weathering, and general surface expression of the geologic units. In addition, the relation of the various geologic units to development and abundance of slope failures was noted.

The oldest exposed rocks in the San Pedro Quadrangle belong to the middle to upper Miocene Altimira Shale Member (Tma) of the Monterey Formation. They underlie much of the uplands and the sea cliff from the western boundary of the quadrangle, near Portuguese Point southeast to about three-fourths of a mile north of Cabrillo Beach, The Altimira Shale consists of siliceous shale, silty and sandy shale, chert shale, chert, siltstone, bituminous shale, diatomaceous shale, diatomite, phosphatic shale, tuffaceous shale, limestone, sandstone, conglomerate, breccia and silicified limestone and shale. Intrusive basaltic rocks (Tb) occur in the lower and middle parts of the Altimira Shale. The basaltic rocks consist of basalt, andesite, volcanic breccia and tuff breccia that forms sills that are more or less concordant with bedding. The basaltic rocks outcrop in three areas of the quadrangle. A large exposure of the basaltic rocks is on the south-facing slopes northeast of Portuguese Bend between elevations of about 400 to 500 feet and about 900 and 1,000 feet. A smaller exposure is less than a mile southeast of San Pedro Hill. These rocks also crop out along the sea cliff at Portuguese Point and Inspiration Point.

The upper Miocene Valmonte Diatomite Member (Tmv) of the Monterey Formation overlies the Altimira Shale and crops out as a band about one mile west of Los Angeles Harbor from the northern boundary of the quadrangle south to about one mile north of Point Fermin. The Valmonte Diatomite consists of diatomaceous shale and diatomite and overlies the Altimira Shale.. The Monterey Formation rests unconformably on the Mesozoic Catalina Schist, which consists of quartz-chlorite schist, quartz-serite schist and quartz-glaucophane-schist. The Catalina Schist forms the basement complex for the entire Palos Verdes Peninsula, but it is not exposed in the San Pedro Quadrangle.

The upper Miocene Magala Mudstone Member (Tmm) of the Monterey Formation overlies the Valmonte Diatomite Member and crops out as a band adjacent to and east of the Valmonte Diatomite from about the northern boundary of the quadrangle south to about 1.5 miles north of Cabrillo Beach. To the south, the Magala Mudstone Member forms the sea cliff from about 1.5 miles north of Cabrillo Beach south to about three-fourths of a mile north of Cabrillo Beach. The unit consists of radiolarian mudstone and diatomite.

The early Pleistocene Lomita Marl (Ql) unconformably overlies the Magala Mudstone Member and forms limited outcrops along a short band adjacent to and east of the Magala Mudstone Member about 2 miles north of Point Fermin. The Lomita Marl consists of marl, calcareous sand and gravel. The late Pleistocene to Holocene Timms Point Silt (Qtp) grades laterally into Lomita Marl and the two units are considered to be facies of the San Pedro Sand. The Timms Point Silt consists of sandy silt and silty sand, and is exposed in a narrow band just east of and adjacent to the Lomita Marl about 2 miles north of Point Fermin. It forms the sea cliff at Timms Point along the Los Angeles Harbor. The early Pleistocene San Pedro Sand (Qsp) overlies the Lomita Marl or Timms Point Silt where these units are present; otherwise it overlies the Magala Mudstone Member. The San Pedro Sand consists of sand, silty sand, silt and gravel and crops out as a band to the east and adjacent to the Lomita Marl, Timms Point Silt or Magala Mudstone Member. It generally forms the sea cliff above the Los Angeles Harbor from north of the sea cliff exposures of the Timms Point Silt to the northern boundary of the quadrangle.

A flight of 13 main emergent marine terraces was mapped in the Palos Verdes Hills by Woodring and others (1946), who numbered the terraces 1 through 13 in ascending order. Intermediate terraces mapped by Woodring and others (1946) include 5a, 7a. The terraces are discontinuous and not all the numbered terraces are exposed everywhere. Cleveland (1976) remapped the terrace distribution in portions of the adjacent Torrance Quadrangle. More recent work, as reported in Bryant (1987), designates several additional intermediate terraces 2a, 2b, 3a, 3b, 4a and 4b. The wavecut platforms of the terraces are typically capped with marine sediments, a nonmarine cover, or, locally, are simply geomorphic benches without significant sedimentary cover.

Terraces 1 through 12 are exposed in the San Pedro Quadrangle. Terraces 1 through 4 and some parts of terraces 8 and 9 are typically capped with upper Pleistocene to Holocene nonmarine terrace deposits (Qter). These are the only terraces shown on the geologic map. Throughout the Palos Verdes Peninsula terraces 6 through 10 have generally lost much to virtually all of their original cover through erosion. The upper Pleistocene to Holocene nonmarine terrace deposits consists of, on the lowest terrace, terrace 1 or 2, a thin marine basal strata of Palos Verdes Sand overlain by nonmarine deposits. The Palos Verdes Sand is undifferentiated from the overlying nonmarine terrace deposits on the geologic map and consists of a few inches to 15 feet of calcareous sand, shell fragments and scattered small pebbles and cobbles. The overlying nonmarine terrace deposits consist of poorly sorted or unsorted, crudely stratified sand, rubble and gravel. This unit is as much as 100 feet thick toward the landward part of the terrace, although the exposed thickness is generally less than 50 feet.

Holocene deposits consist of undifferentiated alluvium (Qal) along some of the stream channels that drain into the Los Angeles Harbor. Alluvium consists of sand, silt, clay and gravel. A more detailed description of the late Quaternary geologic units is presented in the Liquefaction section of this report.

Landslide deposits (Qls) are abundant in the upland portion of the western half of the quadrangle. There are several named large landslides in the San Pedro Quadrangle. They include the Portuguese Bend, Abalone Cove, Flying Triangle, and the Point Fermin landslides. Also, there are a number of small- to moderate-size landslides between the larger landslides that typically occur on the slopes of drainages and along the sea cliff in areas underlain by Altimira Shale or basaltic rocks.

Modern artificial fill (af) is mapped extensively throughout the Los Angeles Harbor facilities, and, locally, at large schools. A more detailed description of the artificial fill is presented in the liquefaction portion (Section 1) of this report.

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, they must first be ranked on the basis of their overall shear strength. Shear strength data for the rock units identified on the geologic map were obtained from geotechnical reports prepared by consultants and on file with the local government permitting departments, (see Appendix A). The locations of rock and soil samples taken for shear testing are shown on Plate 2.1.

Shear strength data gathered from the above sources were compiled for each mapped geologic unit, which were then grouped on the basis of average angle of internal friction (average f) and lithologic character. Geologic formations that have little or no shear test information have been added to existing groups on the basis of lithologic and stratigraphic similarities.

The results of the grouping of geologic materials in the San Pedro Quadrangle are in Tables 2.1 and 2.2.

Structural Geology

The geologic structure of the Palos Verdes Peninsula is dominated by the Palos Verdes Fault and a large, broad northwest-southeast trending doubly plunging anticline (Ehlig, 1982a; Bryant, 1987; Yerkes and others, 1965; and Rowell, 1982). The anticlinal form of the peninsula has been uplifted as a horst between the Palos Verdes fault on the northeast and faults on the sea floor to the southwest. The Palos Verdes Fault is a steep, southwest-dipping reverse fault, upthrown on the southwest, that is exposed along the northeast margin of the Palos Verdes Hills and separates the uplands on the southwest from the flatlands of the Central Plain of the Los Angeles Basin on the northeast. The anticline forms a concave-to-the-south arc from the northwest corner of the

SAN PEDRO QUDRANGLE
SHEAR STRENGTH GROUPINGS

	Formation Name	Number Tests	Mean Phi Value	Group Phi Mean/Median (deg.)	Group C Mean/median (psf)	Phi Values Used in Stability Analyses	Similar LithologNo Data
GROUP 1	Tma(fbc) Tb	41 14	36.3 37.1	36.5/35	680/300	36	
GROUP 2	Qal Qter Tmv	3 8 2	32 31 31	31.2/32	394/300	32	Qlom, Qtp, Ta, Tmal
GROUP 3	Af Qfb	22 6	26.1 26.7	26.2/25.5	493/300	26	Qsp
GROUP 4	Tma(abc)	47	18.4	18.4/19	570/400	18	
GROUP 5	Qls	25	9.8	9.8/8.5	307/209	10	

Table 2.1. Summary of the shear strength statistics for the San Pedro Quadrangle.

SHEAR STRENGTH GROUPS FOR THE SAN PEDRO QUADRANGLE

GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5
Tma(fbc) Tb	Qal Qter Qlom Qtp Tmal Tmv Ta	af Qsp Qtb	Tma(abc)	Qls

Table 2.2. Summary of the shear strength groups for the San Pedro Quadrangle.

Palos Verdes Peninsula, in the area of Flatrock Point, extending toward the southeast to the vicinity of Whites Point. In most places within the anticline the strata are tilted less than 20 degrees.

Other faults and small folds are also present In the San Pedro Quadrangle. Woodring and others (1946) mapped a number of these structures. Those workers mapped a series of broad, approximately northwest-southeast-trending anticlines and adjacent synclines, including the Miraleste Anticline, in the uplands of the center of the quadrangle. The Cabrillo Fault was mapped trending northwest-southeast from between two of three anticlines and extending to the coast near Point Fermin. The Point Fermin Anticline was mapped bisecting the peninsula containing Point Fermin. These folds are likely undulations in the general anticlinal structure of the Palos Verdes Peninsula. Bedding in the geologic units strikes approximately parallel to the trend of the structures with dips that range between 5 and 35 degrees.

We used structural strike and dip information from previous geologic mapping by Woodring and others (1946) and Cleveland (1976) to categorize areas of common stratigraphic dip direction and magnitude, similar to the method presented by Brabb (1983). The dip direction category was compared to the slope aspect (direction) category and, if the same, the dip magnitude and slope gradient categories were compared. If the dip magnitude category was less than or equal to the slope gradient category, and the bedding dip was greater than 25% (4:1 slope), the area was marked as a potential adverse bedding area. This information was then used to subdivide mapped geologic units into areas where fine-grained and coarse-grained strengths would be used.

Landslide Inventory

The evaluation of earthquake-induced landsliding requires an up-to-date and complete picture of the previous occurrence of landsliding. An inventory of the existing landslides in the entire San Pedro Quadrangle was prepared using interpretation of stereo-paired aerial photographs of the study area and limited field reconnaissance (Haydon, unpublished). All areas containing landslides identified in the previous work of Woodring and others (1946), Cleveland (1976), Ehlig (1982a and b; 1987), Lass and Eagen (1982), Kerwin (1982), Ray (1982), Scullin (1987), and Anderson (1987a and b) where re-evaluated during the aerial photograph interpretation conducted for this investigation. Some of the landslides identified in the previous work were not included in the landslide inventory because in our reevaluation it was concluded the feature was not a landslide, while many additional landslides were identified and the boundaries of many of the landslides were modified from the previous work.

The completed hand-drawn landslide map was scanned, digitized and the database was attributed with landslide information on confidence of interpretation (definite, probable, or questionable) and other properties, such as activity, thickness, and associated geologic unit(s). To keep the landslide inventories of consistent quality, all landslides originally depicted on the digitized geologic map were deleted and only those included in the DMG inventory were incorporated into the hazard-evaluation process. A version of this landslide inventory is included with Plate 2.1.

PART II

EARTHQUAKE-INDUCED LANDSLIDE GROUND SHAKING OPPORTUNITY

Design Strong-Motion

The Newmark analysis used in delineating the earthquake-induced landslide zones requires the selection of a design earthquake strong-motion record. For the San Pedro Quadrangle, the selection was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10% probability of being exceeded in 50 years (Petersen and others, 1996; Cramer and Petersen, 1996). The parameters used in the record selection are:

Modal Magnitude:	7.1
Modal Distance:	2.5 to 11.1 km
PGA:	0.36 to 0.55 g

The strong-motion record selected was the Channel 3 (N35°E horizontal component) University of Southern California Station #14 recording from the magnitude 6.7 Northridge Earthquake (Trifunac and others, 1994). This record had a source to recording site distance of 8.5 km and a PGA of 0.59 g. The selected strong-motion record was not scaled or otherwise modified prior to analysis.

Displacement Calculation

To develop a relationship between the yield acceleration (a_y; defined as the horizontal ground acceleration required to cause the factor of safety to equal 1.0) and Newmark displacements, the design strong-motion record was integrated twice for a given a_y to find the corresponding displacement, and the process repeated for a range of a_y (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for any combination of geologic material strength and slope angle, as represented by the yield acceleration. We used displacements of 30, 15 and 5 cm as criteria for rating levels of earthquake shaking damage on the basis of the work of Youd (1980), Wilson and Keefer (1983), and the DMG pilot study for earthquake-induced landslides (McCrink and Real, 1996). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.076, 0.129 and 0.232 g. Because these yield acceleration values are derived from the design strong-motion record, they represent the significant ground-shaking opportunity thresholds for the San Pedro Quadrangle.

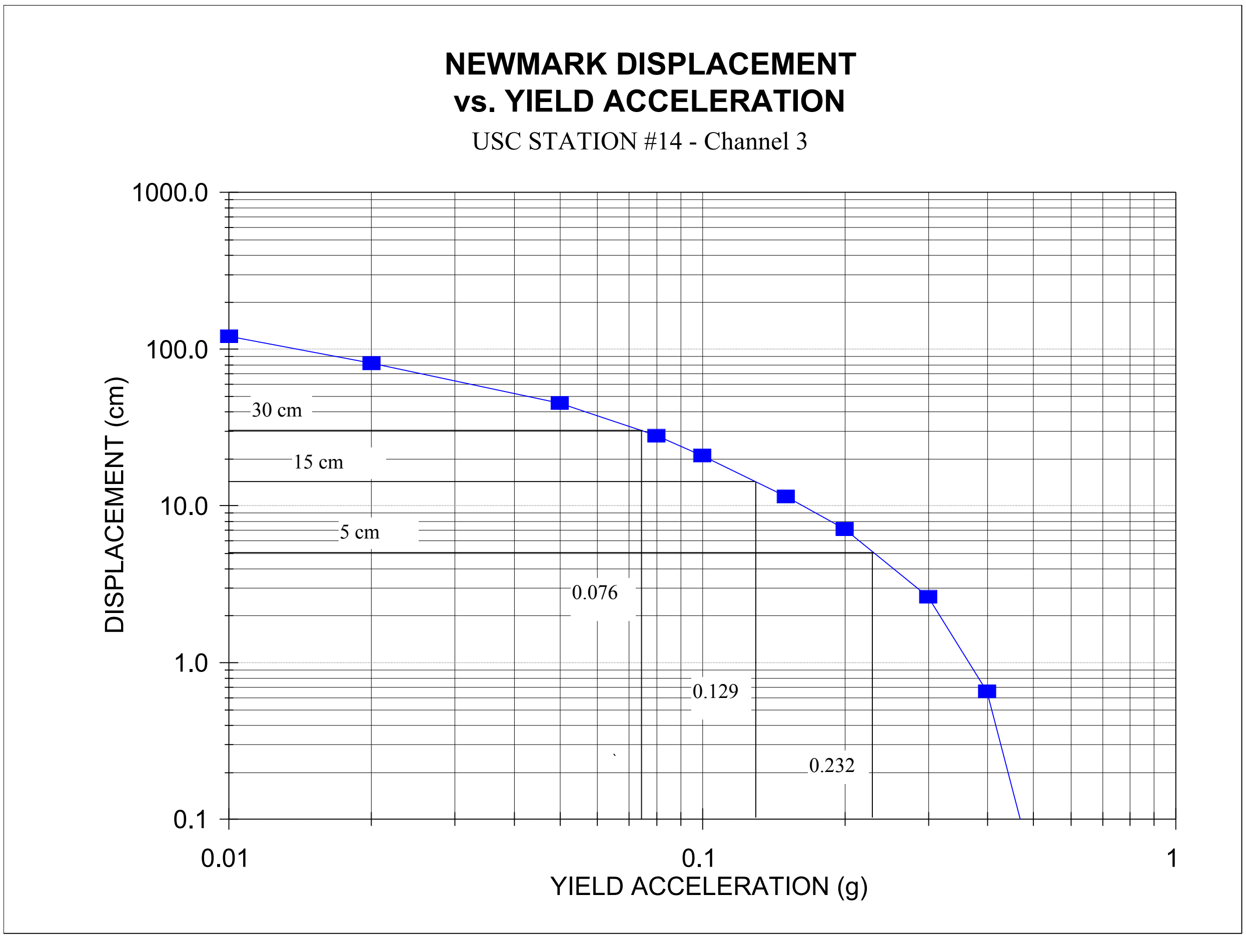


Figure 2.1. Yield acceleration vs. Newmark displacement for the USC Station # 14 strong-motion record From the 17 January 1994 Northridge, California Earthquake.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Terrain Data

The calculation of slope gradient is an essential part of evaluating slope stability under earthquake conditions. To calculate slope gradient for the terrain within the San Pedro Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the U.S. Geological Survey. This DEM has a 10-m horizontal resolution and a 7.5-m vertical accuracy (USGS, 1993) and was prepared from topographic contours based on 1963 photographs.

Areas that have undergone large-scale grading since 1963 as part of residential development were identified (see Plate 2.1) on 1: 40,000-scale aerial photography flown in 1994 and 1995 (NAPP, 1994). Photogrammetric DEM's covering the graded areas were prepared by the U.S. Bureau of Reclamation with ground control points established by DMG. The photogrammetric DEM's were then merged into the USGS DEM, replacing the areas of out-dated elevation data. Surrounding quadrangle DEM's were merged with the San Pedro DEM to avoid the loss of data at the quadrangle edges when the slope calculations were performed.

Slope-gradient maps were made from both sets of DEM's using a third-order finite-difference center-weighted algorithm (Horn, 1981). The slope-gradient map was used in conjunction with the geologic strength map to prepare the earthquake-induced landslide hazard potential map.

Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of 1 degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by the calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1)g \sin \alpha$$

where FS is the Factor of Safety, g is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure α is the same as the slope angle.

The yield acceleration calculated by Newmark's equation represents the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. The acceleration values were compared with the ground shaking opportunity, defined by Figure 2.1, to determine the earthquake-induced landslide hazard potential. Based on the criteria described in Figure 2.1 above, if the calculated yield acceleration was less than 0.076g, expected displacements could be greater than 30 cm, and a HIGH (H on Table 2.3) hazard potential was assigned. Likewise, if the calculated a_y fell between 0.076 and 0.129g a MODERATE (M on Table 2.3) potential was assigned, between 0.129 and 0.232 a LOW (L on Table 2.3) potential was assigned, and if a_y were greater than 0.232g a VERY LOW (VL on Table 2.3) potential was assigned.

Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

SAN PEDRO QUDRANGLE HAZARD POTENTIAL MATRIX														
Geologic Material Group	Mean Phi	SLOPE CATEGORY (Percent)												
		I 0-5	II 6-9	III 10-19	IV 20-23	V 24-35	VI 36-37	VII 38-41	VIII 42-46	IX 47-48	X 49-54	XI 55-59	XII 60-64	XIII >64
1	36	VL	VL	VL	VL	VL	VL	VL	VL	L	L	L	M	H
2	32	VL	VL	VL	VL	VL	VL	L	L	L	M	H	H	H
3	26	VL	VL	VL	VL	L	M	M	H	H	H	H	H	H
4	18	VL	VL	L	M	H	H	H	H	H	H	H	H	H
5	10	L	M	H	H	H	H	H	H	H	H	H	H	H

Table 2.3. Hazard potential matrix for earthquake-induced landslides in the San Pedro Quadrangle. Shaded area indicates hazard potential levels included in the hazard zone.

EARTHQUAKE-INDUCED LANDSLIDE ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (in press). Under those criteria, earthquake-induced landslide zones are areas meeting one or more of the following:

1. Areas known to have experienced earthquake-induced slope failure during historic earthquakes.

2. Areas identified as having past landslide movement, including both landslide deposits and source areas.

3. Areas where CDMG's analyses of geologic and geotechnical data indicate that the geologic materials are susceptible to earthquake-induced slope failure.

Existing Landslides

Studies of the types of landslides caused by earthquakes (Keefer, 1984) show that re-activation of the whole mass of deep-seated landslide deposits is rare. However, it has been observed that the steep scarps and toe areas of existing landslides, which formed as a result of previous landslide movement, are particularly susceptible to earthquake-induced slope failure. In addition, because they have been disrupted during landslide movement, landslide deposits are inferred to be weaker than coherent, undisturbed, adjacent source rocks. Finally, we felt that a long duration, San Andreas fault-type earthquake could be capable of initiating renewed movement in existing deep-seated landslide deposits. Therefore, all existing landslides identified in the inventory with a definite or probable confidence of interpretation were included in the hazard zone.

Geologic and Geotechnical Analysis

On the basis of a DMG pilot study (McCrink and Real, 1996), the earthquake-induced landslide zone includes all areas determined to lie within the High, Moderate, and Low levels of hazard potential. Therefore, as shown in Table 2.3, geologic material strength group 5 is always included in the zone, strength group 4 is in the zone for all slopes greater than 9%, strength group 3 above 23%, strength group 2 above 37% and strength group 1, the strongest rock types, were zoned for slope gradients above 46%. This results in roughly 26% (1,500 acres) of the upland, hilly portion of the San Pedro Quadrangle lying within the earthquake-induced landslide zone.

ACKNOWLEDGMENTS

The authors thank staff from the City of Rancho Palos Verdes and County of Los Angeles, Department of Public Works, Material Engineering Division for their assistance in obtaining geotechnical information used in the preparation of this report. Technical review of the methodology was provided by Bruce Clark, Randy Jibson, Robert Larson, Scott Lindvall, and J. David Rogers, who are members of the State Mining and Geology Board's Seismic Hazards Mapping Act Advisory Committee Landslides Working Group. At DMG, special thanks to Bob Moskovitz, Teri McGuire, Scott Shepherd and Barbara Wanish for their Geographic Information System operations support. Thanks also to the Bureau of Reclamation staff who built the DEM's, Tim McCrink and Rick Wilson for providing assistance with digitizing terrain in graded areas, Joy Arthur for designing and plotting the graphic displays associated with the earthquake-induced landslide zone map, and to Lisa Chisholm for preparing the landslide attribute tables for input into this report.

REFERENCES

Anderson, J.L., 1987a, Deformation in the coastal portion of the Abalone Cove Landslide, a natural laboratory for the study of tectonics in miniature, *in* Fischer, P.J., *editor*, Geology of the Palos Verdes Peninsula and San Pedro Bay, Society of Economic Paleontologists and

Mineralogists & American Association of Petroleum Geologists Field Trip Guidebook, June 7.

Anderson, J.L., 1987b, The Flying Triangle Landslide: geologic, geomorphologic, and tectonic controls, *in* Fischer, P.J., *editor*, Geology of the Palos Verdes Peninsula and San Pedro Bay, Society of Economic Paleontologists and Mineralogists & American Association of Petroleum Geologists Field Trip Guidebook, June 7.

Bezore, S.P., Saucedo, G.J. and Greenwood, R. G., (unpublished), Geologic Map of the Long Beach 100,000-scale Quadrangle.

Brabb, E.E., 1983, Map showing direction and amount of bedding dip of sedimentary rocks in San Mateo County, California: U.S. Geological Survey Miscellaneous Investigations Series Map I-1257C, 1 sheet, scale 1:62,500.

Bryant, M.E., 1982, Geomorphology, neotectonics, and ages of marine terraces, Palos Verdes Peninsula, *in* Cooper, J.D., *compiler*, Landslides and Landslide Abatement, Palos Verdes Peninsula, Southern California, Association of Engineering Geologist, Southern California Section, Guidebook and Volume, Field Trip Number 10.

Bryant, M.E., 1987, Emergent marine terraces and Quarternary tectonics, Palos Verdes Peninsula, California, *in* Fischer, P.J., *editor*, Geology of the Palos Verdes Peninsula and San Pedro Bay, Society of Economic Paleontologists and Mineralogists & American Association of Petroleum Geologists Field Trip Guidebook, June 7.

California State Mining and Geology Board, 1997, Guidelines for evaluating and mitigating seismic hazards in California: California Department of Conservation, Division of Mines and Geology, Special Publication 117, 74 p.

California State Mining and Geology Board, in press, Criteria for delineating seismic hazard zones: California Department of Conservation, Division of Mines and Geology, Special Publication 118, 21 p.

Cleveland, G.B., 1976, Geology of the northeast part of the Palos Verdes Hills, Los Angeles County, California: California Division of Mines and Geology, Map Sheet 27, map scale - 1:12,000.

Cramer, C.H. and Petersen, M.D., 1996, Predominant seismic source distance and magnitude maps for Los Angeles, Orange and Ventura counties, California: Bulletin of the Seismological Society of America, v. 85, no. 5, p. 1645-1649.

Ehlig, P.L., 1982 a, The Palos Verdes Peninsula: It’s physiography, land use and geologic setting, *in* Cooper, J.D., *compiler*, Landslides and landslide abatement, Palos Verdes Peninsula, Southern California, Association of Engineering Geologist, Southern California Section, Guidebook and Volume, Field Trip Number 10.

Ehlig, P.L., 1982 b, Mechanics of the Abalone Cove Landslide including the role of ground water in landslide stability and a model for development of large landslides in the Palos Verdes Hills, *in* Cooper, J.D., *compiler*, Landslides and landslide abatement, Palos Verdes Peninsula, Southern California, Association of Engineering Geologist, Southern California Section, Guidebook and Volume, Field Trip Number 10.

Ehlig, P.L., 1987, The Portuguese Bend Landslide stabilization project, *in* Fischer, P.J., *editor*, Geology of the Palos Verdes Peninsula and San Pedro Bay, Society of Economic Paleontologists and Mineralogists & American Association of Petroleum Geologists Field Trip Guidebook, June 7.

Haydon, W. D., 1998, unpublished, Landslide inventory map of the San Pedro 7.5-minute Quadrangle, Los Angeles County, California.

Horn, B.K.P., 1981, Hill shading and the reflectance map: Proceedings of the IEEE, v. 69, no. 1, p. 14-47.

Jibson, R.W., 1993, Predicting earthquake-induced landslide displacements using Newmark's sliding block analysis: Transportation Research Board, National Research Council, Transportation Research Record 1411, 17 p.

Keefer, D.K., 1984, Landslides caused by earthquakes: Geological Society of America Bulletin, v. 95, no. 4, p. 406-421.

Kerwin, S.T., 1982, Land stability in the Klondike Canyon area, *in* Cooper, J.D., *compiler*, Landslides and Landslide Abatement, Palos Verdes Peninsula, Southern California, Association of Engineering Geologist, Southern California Section, Guidebook and Volume, Field Trip Number 10.

Lass, G.L., and Eagen, J.T., 1982, Introduction to the Abalone Cove Landslides, *in* Cooper, J.D., *compiler*, Landslides and Landslide Abatement, Palos Verdes Peninsula, Southern California, Association of Engineering Geologist, Southern California Section, Guidebook and Volume, Field Trip Number 10.

Leighton & Associates, 1990, Technical Appendix to the Safety Element of the Los Angeles County General Plan, Hazard Reduction in Los Angeles County, Volumes 1 and 2.

McCrink, T.P. and Real, C.R., 1996, Evaluation of the Newmark method for mapping earthquake-induced landslide hazards in the Laurel 7-1/2 minute Quadrangle, Santa Cruz County, California: California Division of Mines and Geology Final Technical Report for U.S. Geological Survey Contract 143-93-G-2334, U.S. Geological Survey, Reston, Virginia, 31 p.

Newmark, N.M., 1965, Effects of earthquakes on dams and embankments: Geotechnique, v. 15, no. 2, p. 139-160.

Norris, R.M. and Webb, R.W., 1990, Geology of California: John Wiley & Sons, Inc.

Petersen, M.D., Cramer, C.H., Bryant, W.A., Reichle, M.S. and Toppozada, T.R., 1996, Preliminary seismic hazard assessment for Los Angeles, Ventura, and Orange counties, California, affected by the January 17, 1994 Northridge earthquake: Bulletin of the Seismological Society of America, v. 86, no. 1B, p. S247-S261.

Ray, M.E., 1982, Geologic investigation, grading stabilization measures, and development of the South Shores Landslide, *in* Cooper, J.D., *compiler*, Landslides and Landslide Abatement, Palos Verdes Peninsula, Southern California, Association of Engineering Geologist, Southern California Section, Guidebook and Volume, Field Trip Number 10.

Rowell, H.C., 1982, Chronostratigraphy of the Monterey Formation of the Palos Verdes Hills, *in* Cooper, J.D., *compiler*, Landslides and Landslide Abatement, Palos Verdes Peninsula, Southern California, Association of Engineering Geologist, Southern California Section, Guidebook and Volume, Field Trip Number 10.

Scullin, M., 1987, Point Fermin Landslide, *in* Fischer, P.J*., editor*, Geology of the Palos Verdes Peninsula and San Pedro Bay, Society of Economic Paleontologists and Mineralogists & American Association of Petroleum Geologists Field Trip Guidebook, June 7.

Smith, T.C., 1996, Preliminary maps of seismic hazard zones and draft guidelines for evaluating and mitigating seismic hazards: California Geology, v. 49, no. 6, p. 147-150.

Trifunac, M.D., Todorovska, M.I. and Ivanovic, S.S., 1994, A note on distribution of uncorrected peak ground accelerations during the Northridge, California earthquake of 17 January 1994: Soil Dynamics and Earthquake Engineering, v. 13, no. 3, p. 187-196.

U.S. Geological Survey, 1993, Digital Elevation Models: National Mapping Program, Technical Instructions, Data Users Guide 5, 48 p.

Wilson, R.C. and Keefer, D.K., 1983, Dynamic analysis of a slope failure from the 1979 Coyote Lake, California, earthquake: Bulletin of the Seismological Society of America, v. 73, p. 863-877.

Woodring, W.P., Bramlette, M.N. and Kew, W.S.W., 1946, Geology and paleontology of Palos Verdes Hills, California: U.S. Geological Survey Professional Paper 207, map scale 1:24,000.

Yerkes, R.F., McCulloh, T.H., Schoellhamer, J.E. and Vedder, J.G., 1965, Geology of the Los Angeles basin, California-An introduction: U.S. Geological Survey Professional Paper 420-A, 57 p.

Youd, T.L., 1980, Ground failure displacement and earthquake damage to buildings: American Society of Civil Engineers Conference on Civil Engineering and Nuclear Power, 2d, Knoxville, Tennessee, 1980, v. 2, p. 7-6-2 to 7-6-26.

AIR PHOTOS

NAPP, 1994, U.S. Geological Survey-National Aerial Photography Program (NAPP), flight 6862, frames 1-5, 71-73, flown 6/1/94, black and white, vertical, approximate scale 1:40,000.

United States Department of Agriculture (USDA), dated 11-4-52, Flight or Serial number AXJ, Photo numbers 4K-123-125, scale 1:20,000±.

United States Department of Agriculture (USDA), dated 8-31-54, Flight or Serial number AXJ, Photo numbers 19K-16-18, scale 1:20,000±.

United States Department of Agriculture (USDA), dated 6-4-53, Flight or Serial number AXJ, Photo numbers 13K-101-105, scale 1:20,000±.

APPENDIX A
SOURCES OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
Division of Mines and Geology, Environmental Impact Reports File	64
City of Rancho Palos Verdes, Planning Department	27
County of Los Angeles, Department of Public Works, Materials Engineering Division	77
Total number of tests used to characterize the units in the San Pedro Quadrangle	168

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the San Pedro 7.5-Minute Quadrangle, Los Angeles County, California

By

Mark D. Petersen, Chris H. Cramer, Geoffrey A. Faneros, Charles R. Real, and Michael S. Reichle

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included, are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5- minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the "Simple Prescribed Parameter Value" method (SPPV) described in the site investigation guidelines (California State Mining and Geology Board, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections I and II, addressing liquefaction and earthquake-induced landslide hazards, constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the seismogenic sources as published in the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology, and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10% probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

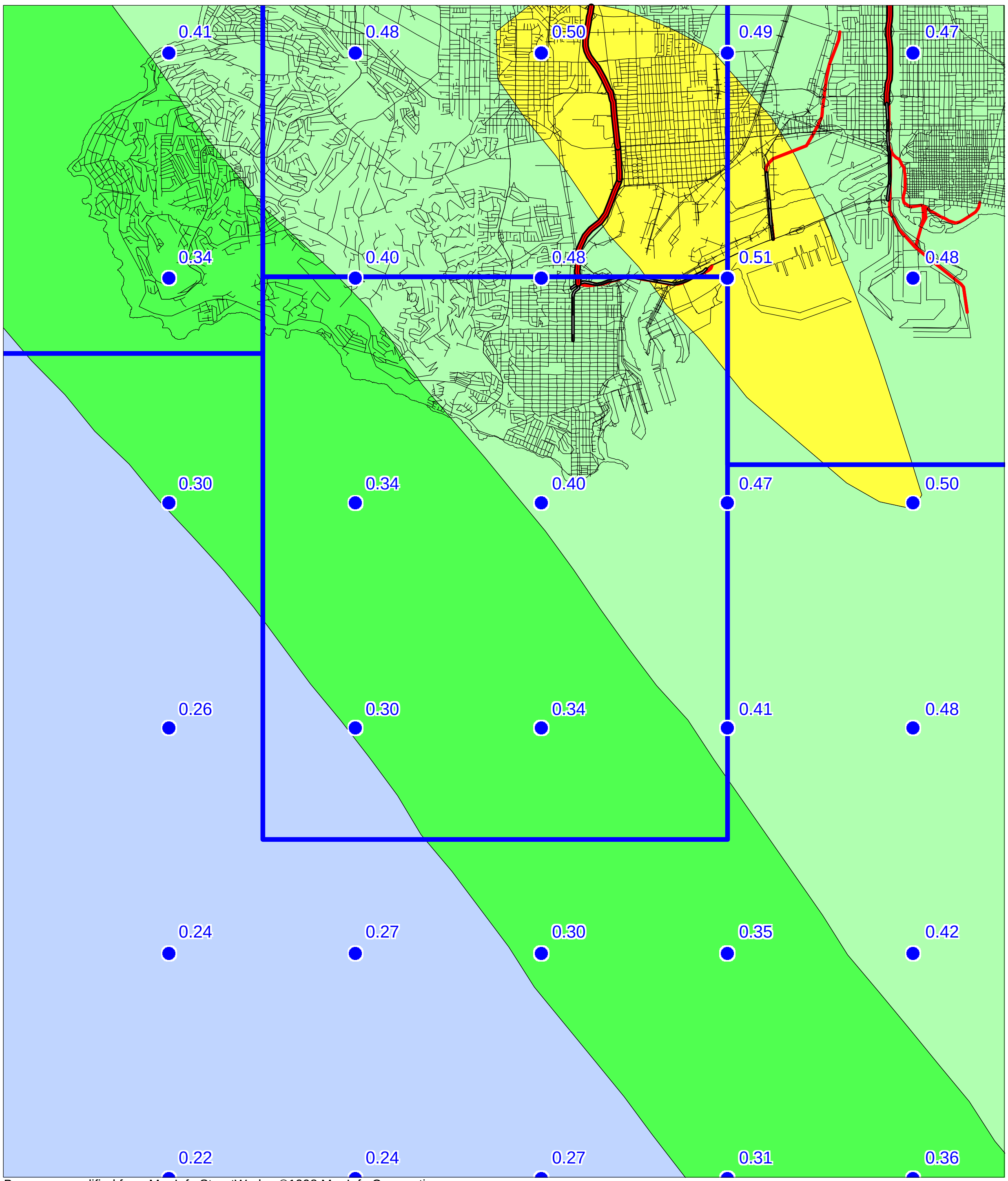
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight adjacent quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

SAN PEDRO 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation

0 2.5 5

Kilometers

Department of Conservation
Division of Mines and Geology

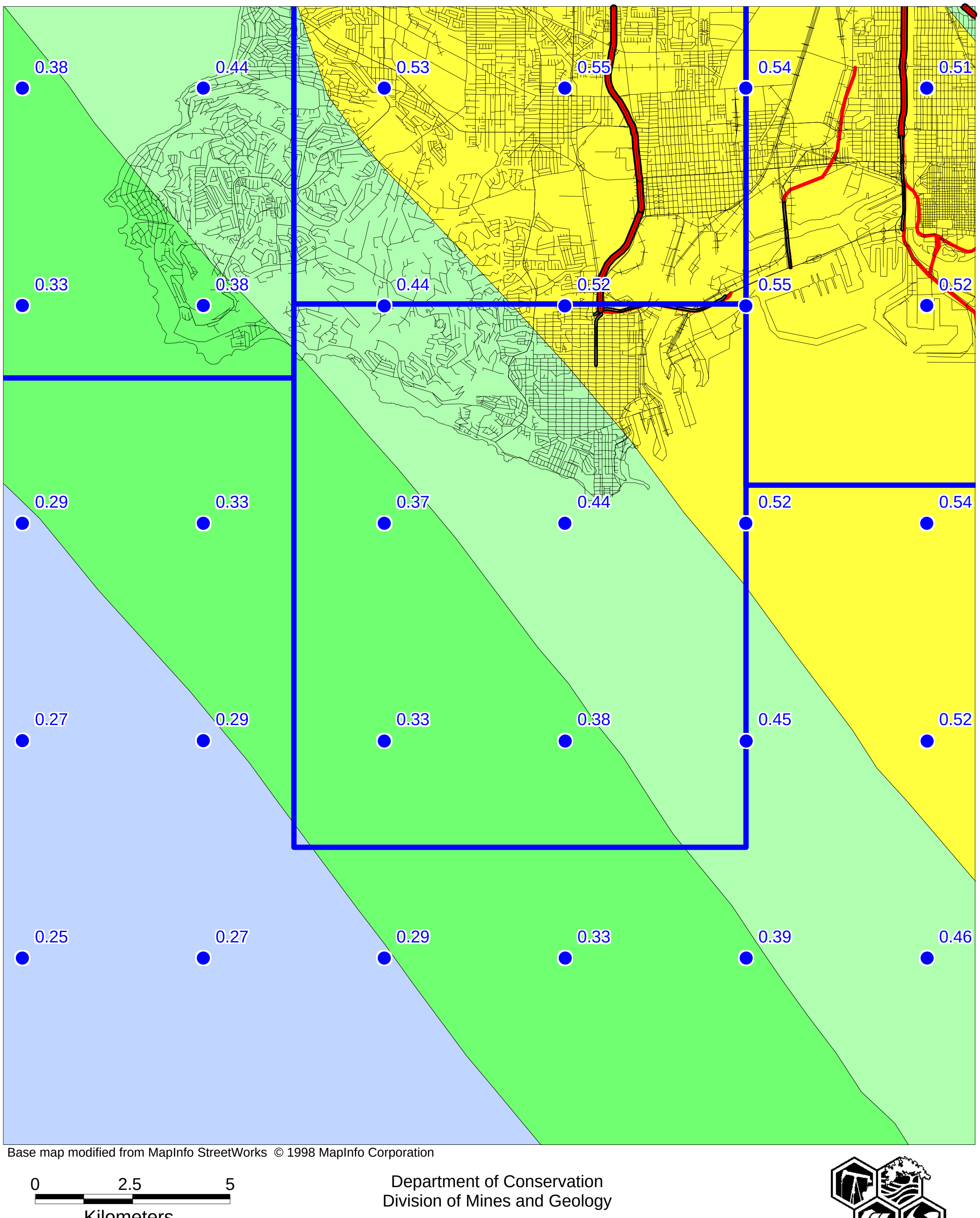
Figure 3.1

SAN PEDRO 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



Department of Conservation
Division of Mines and Geology

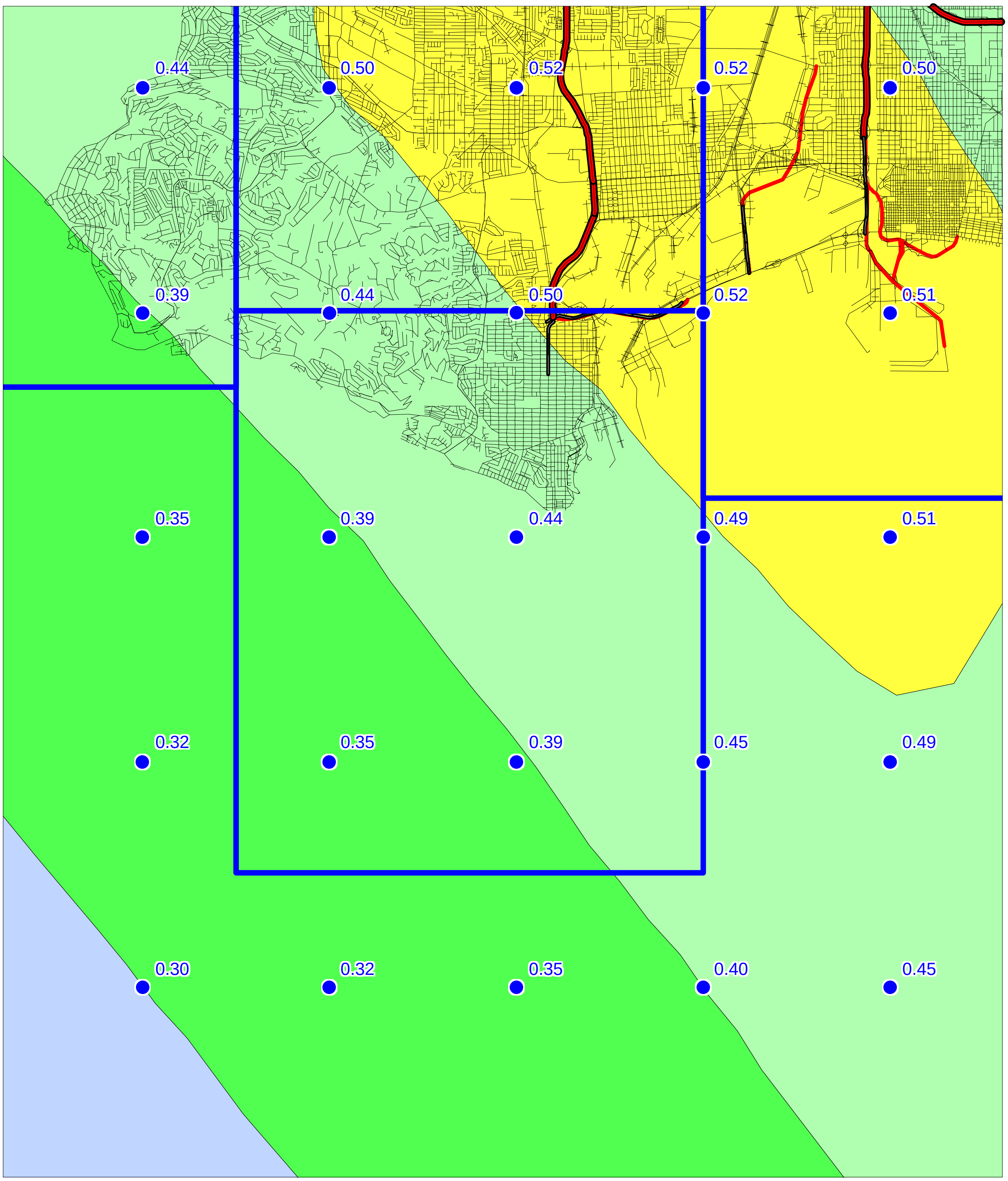
Figure 3.2

SAN PEDRO 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

ALLUVIUM CONDITIONS



Base map modified from MapInfo Street Works ©1998 MapInfo Corporation

0 2.5 5

Kilometers

Department of Conservation
Division of Mines and Geology

Figure 3.3

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10% probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

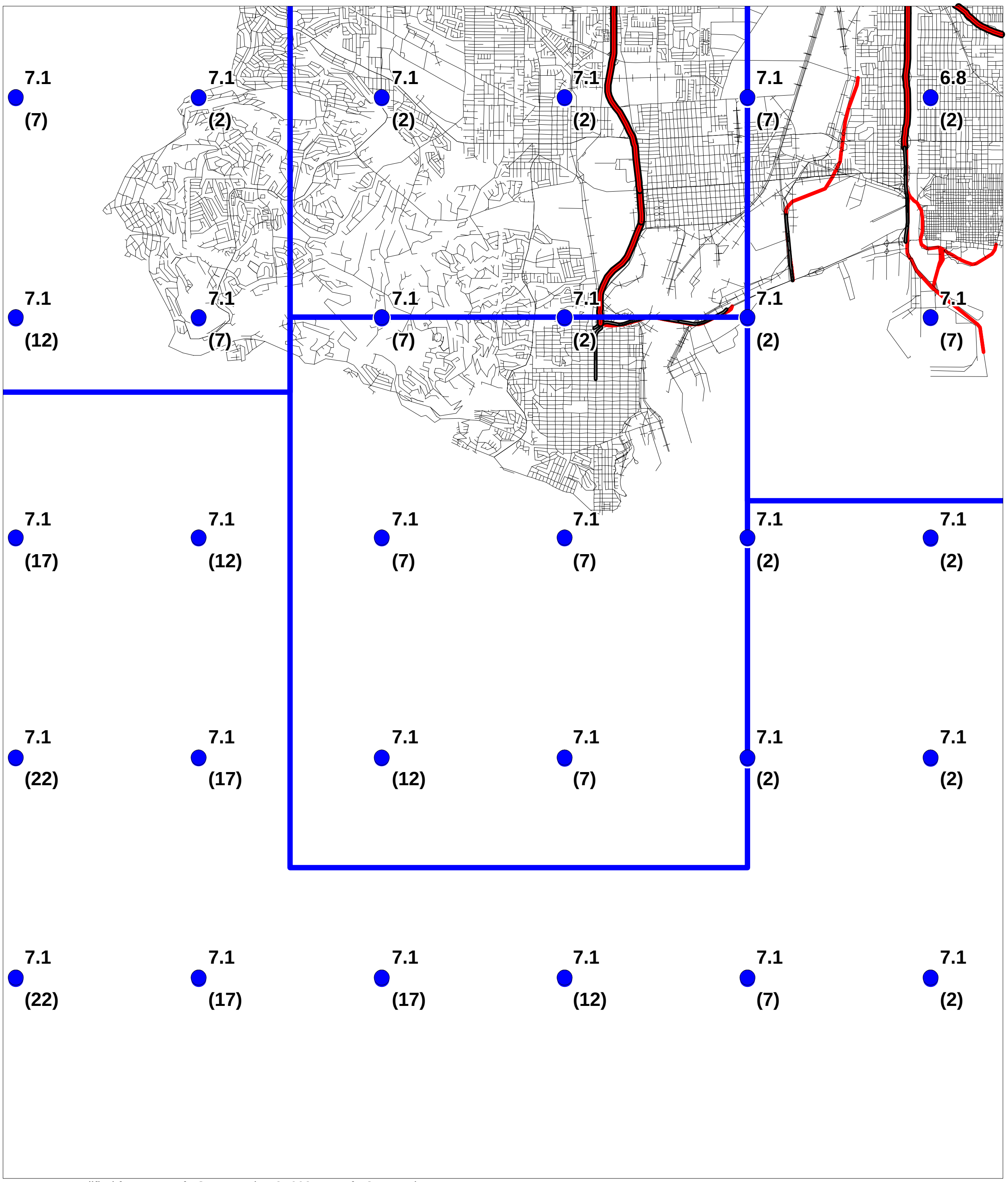
2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual

SAN PEDRO 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

Figure 3.4

ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.

3. Uncertainties in the hazard values have been estimated to be about +/- 50% of the ground motion value at two standard deviations (Cramer and others, 1996).

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not previously been recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (California State Mining and Geology Board, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the “importance” or sensitivity of the proposed building with regard to occupant safety.

REFERENCES

Boore, D.M., Joyner, W.B. and Fumal, T.E., 1997, Empirical near-source attenuation relationships for horizontal and vertical components of peak ground acceleration, peak ground velocity, and pseudo-absolute acceleration response spectra: Seismological Research Letters, v. 68, p. 154-179.

California State Mining and Geology Board, 1997, Guidelines for evaluating and mitigating seismic hazards in California: California Department of Conservation, Division of Mines and Geology, Special Publication 117, 74 p.

Campbell, K.W., 1997, Attenuation relationships for shallow crustal earthquakes based on California strong motion data: Seismological Research Letters, v. 68, p. 180-189.

Cramer, C.H. and Petersen, M.D., 1996, Predominant seismic source distance and magnitude maps for Los Angeles, Orange and Ventura counties, California: Bulletin of the Seismological Society of America, v. 85, no. 5, p. 1645-1649.

Cramer, C.H., Petersen, M.D. and Reichle, M.S., 1996, A Monte Carlo approach in estimating uncertainty for a seismic hazard assessment of Los Angeles, Ventura, and Orange counties, California: Bulletin of the Seismological Society of America, v. 86, p. 1681-1691.

International Conference of Building Officials (ICBO), 1997, Uniform Building Code: v. 2, Structural engineering and installation standards, 492 p.

Jennings, C.W., *compiler*, 1994, Fault activity map of California and adjacent areas: California Department of Conservation, Division of Mines and Geology, California Geologic Data Map Series, map no. 8.

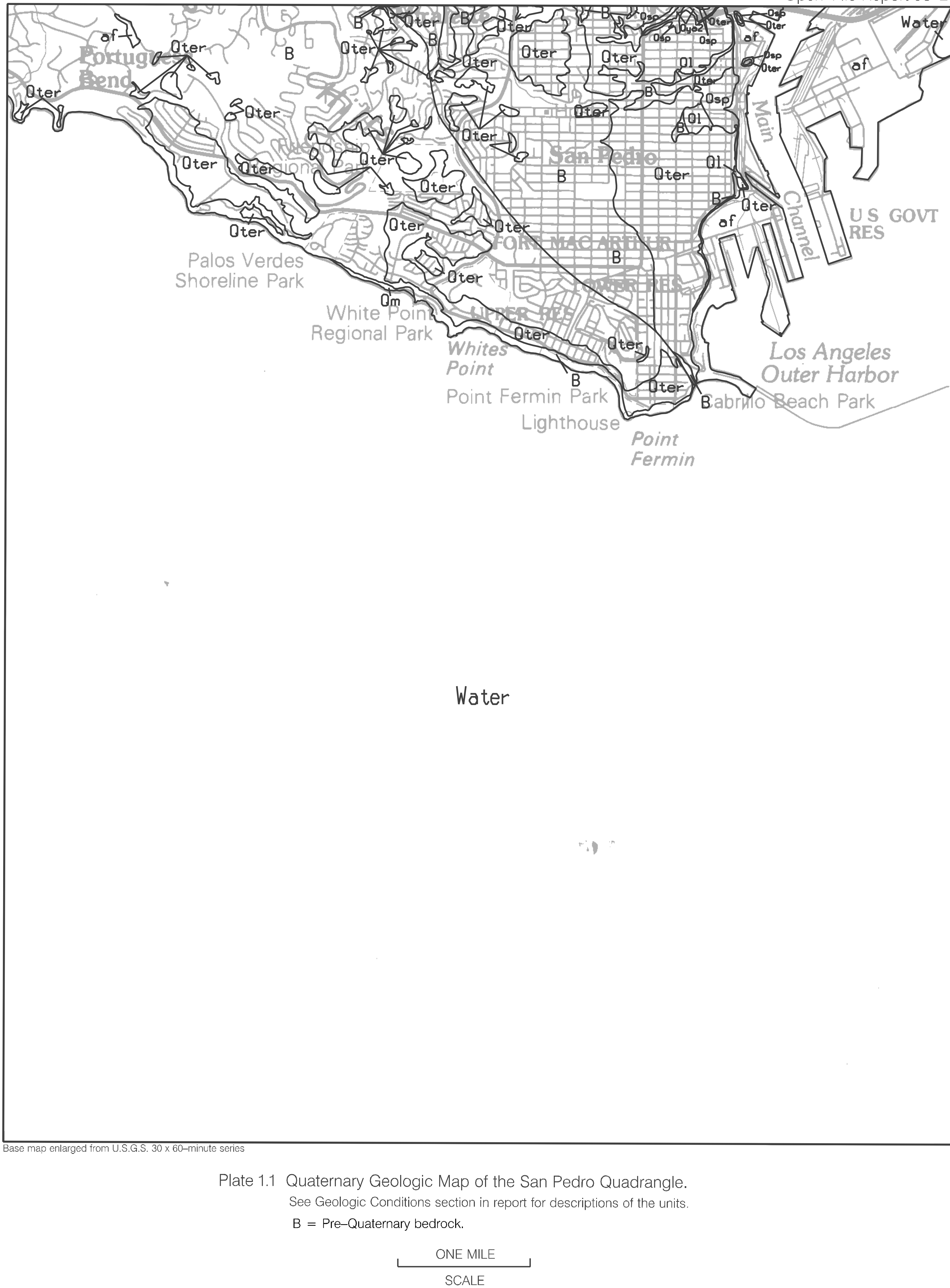
Petersen, M.D., Bryant, W.A., Cramer, C.H., Cao, T., Reichle, M.S., Frankel, A.D., Lienkaemper, J.J., McCrory, P.A. and Schwartz, D.P., 1996, Probabilistic seismic hazard assessment for the State of California: California Department of Conservation, Division of Mines and Geology Open-File Report 96-08; also U.S. Geological Survey Open-File Report 96-706, 66 pp.

Sadigh, K., Chang, C.-Y., Egan, J.A., Makdisi, F. and Youngs, R.R., 1997, SEA96- A new predictive relation for earthquake ground motions in extensional tectonic regimes: Seismological Research Letters, v. 68, p. 190-198.

Wilson, R.C. and Keefer, D.K., 1983, Dynamic analysis of a slope failure from the 1979 Coyote Lake, California, Earthquake: Bulletin of the Seismological Society of America, v. 73, p. 863-877.

Youd, T.L. and Idriss I.M., 1997, Proceedings of the NCEER workshop on evaluation of liquefaction resistance of soils: Technical Report NCEER-97-0022, 40 p.

Youngs, R.R., Chiou, S.-J., Silva, W.J. and Humphrey, J.R., 1997, Stochastic point-source modeling of ground motions in the Cascadia Region: Seismological Research Letters, v. 68, p. 74-85.

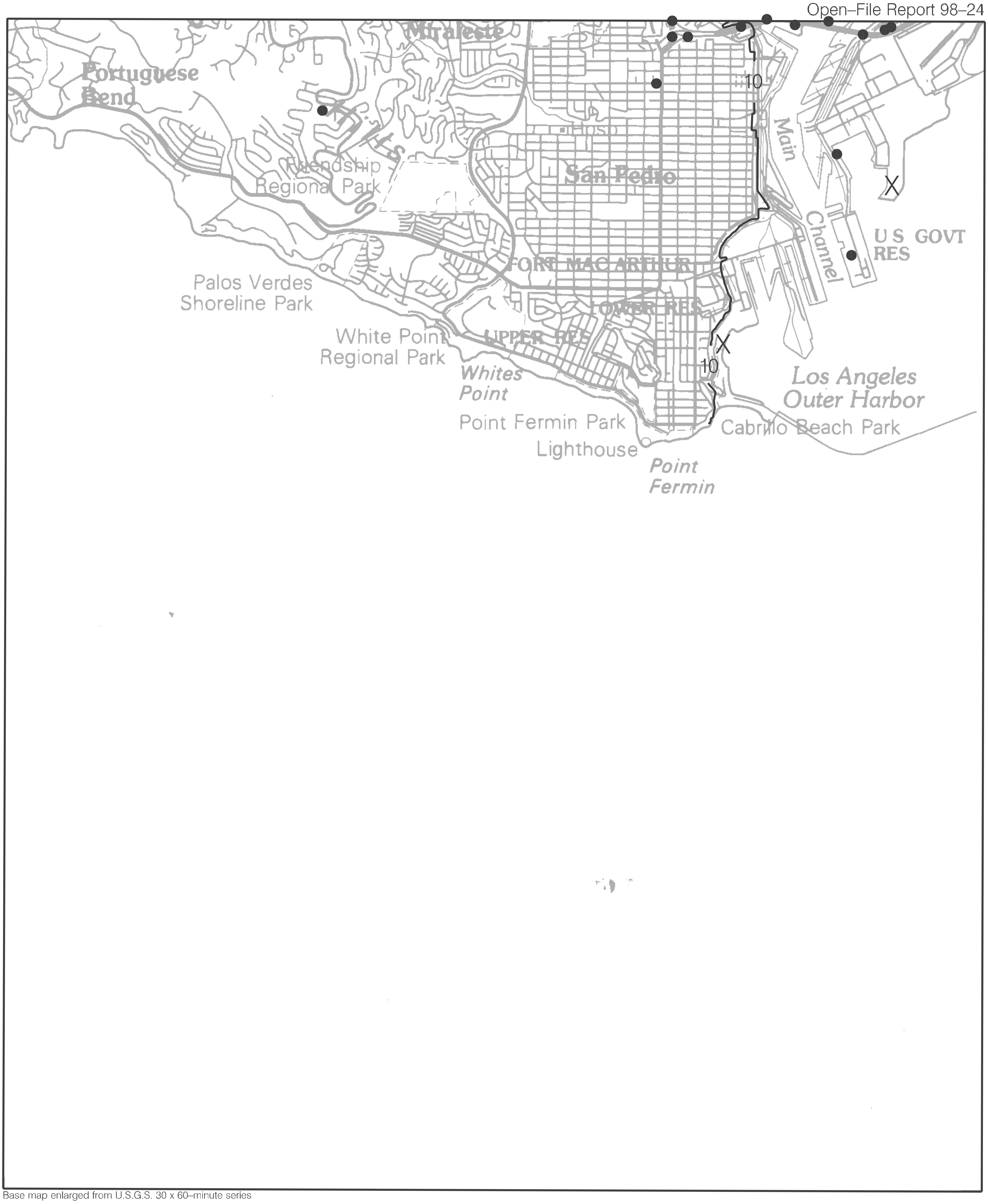


Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 1.1 Quaternary Geologic Map of the San Pedro Quadrangle.

See Geologic Conditions section in report for descriptions of the units.

B = Pre–Quaternary bedrock.



Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 1.2 Historically Highest Ground Water Contours and Borehole Log Data Locations, San Pedro Quadrangle.

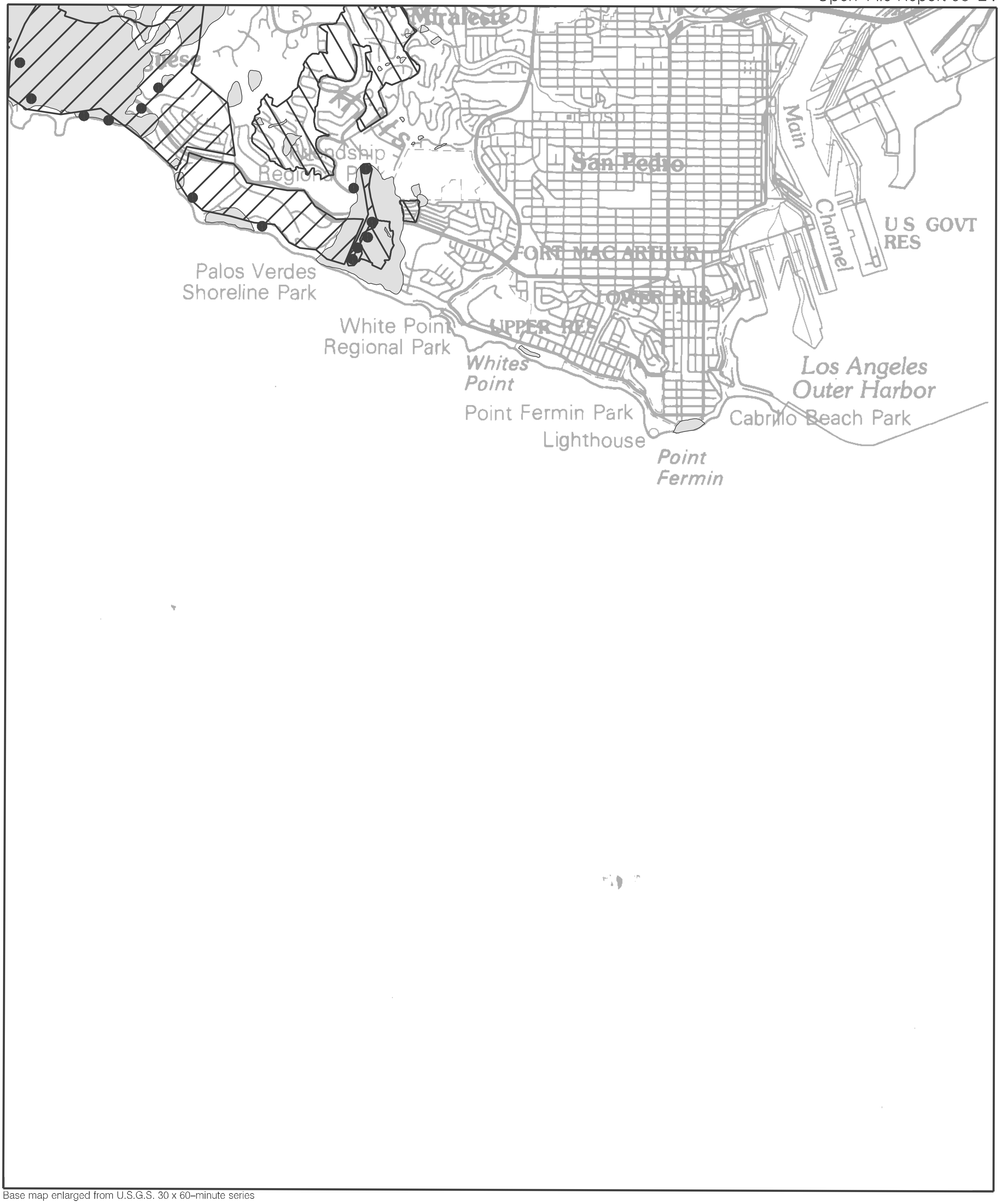
● Borehole Site

30 Depth to ground water in feet

X Site of historical earthquake–generated liquefaction. See "Areas of Past Liquefaction" discussion in text.

ONE MILE

SCALE



Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 2.1 Landslide inventory, Shear Test Sample Locations, and Areas of Significant Grading, San Pedro Quadrangle.

● shear test sample location   landslide   areas of significant grading   tract report with multiple borings

ONE MILE

SCALE